Shelby Ceirse
Taylor Larrechea

+9.5/10

Laboratory 9: Currents and Magnetic Fields

Electric currents produce magnetic fields. These fields will exert forces on compasses and other currents. This laboratory explores the fields produced by currents. In one experiment these will be used to determine a component of Earth's magnetic field. In another experiment theses ideas will be used to investigate the force that one current exerts on another.

1 Field Produced by a Current Carrying Coil: Determining the Earth's Magnetic Field

In this experiment a circular coil will be oriented vertically so that the Earth's magnetic field lies in the plane of the coil. Figure 1 illustrates this as viewed from above. A current passes through the coil and this produces a magnetic field at the center of the coil that points along the axis of the coil (i.e. perpendicular to the coil). This will combine with the Earth's magnetic field to produce a net magnetic field. Determining the field produced by the coil and the direction of the net magnetic field will allow one to determine the field produced by Earth.

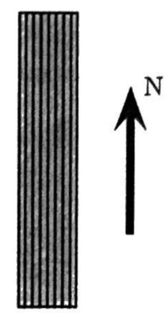
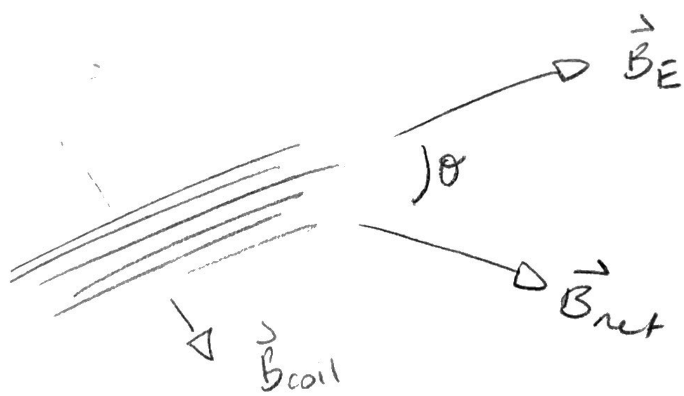


Figure 1: Coil in Earth's field.

a) Sketch one of the two possible directions of the field produced by the coil, $\vec{B}_{\text{coil}}$. Sketch the field produced by Earth, $\vec{B}_{\text{Earth}}$. Add these vectors graphically to illustrate the net magnetic field vector, $\vec{B}_{\text{net}} = \vec{B}_{\text{coil}} + \vec{B}_{\text{Earth}}$.

✓



b) Let θ be the angle between north and $\vec{B}_{\text{net}}$. Indicate this angle on your sketch. You will be able to measure θ and also B_{coil}, the magnitude of $\vec{B}_{\text{coil}}$. Describe *how* you could use this to determine the magnitude of $\vec{B}_{\text{Earth}}$. You should arrive at a formula that relates B_{Earth} to B_{coil} and θ. Ensure that the instructor checks your result.

$B_{net} = B_{coil} + B_{earth}$

$= \tan^{-1}\left(\frac{\vec{B}_{coil}}{\vec{B}_{earth}}\right)$

$\vec{B}_{coil} / \tan(\theta) = B_{earth}$ ✓

This experiment uses a circular current-carrying coil with N complete loops of wire. The magnetic field at the center of the loop points along the axis of the loop in a direction given by the right hand rule. The magnitude of the magnetic field at the center of the loop is given by

$$B_{\text{coil}} = N\frac{\mu_0 I}{2R} \tag{1}$$

where $\mu_0 = 4\pi \times 10^{-7}\,\text{Tm/A}$ is a constant called the permeability of free space, R is the radius of the loop and I the current through the loop. Eq. (1) is what you will use to determine the magnitude of the field produced by the coil.

$d = .12\text{m}$

c) Place the compass at the center of the loop and orient the loop so that the plane of the loop lies along the north-south direction. Then orient the compass base so that the 0° mark points north along the loop plane.

d) Adjust the current through the coil so that the compass needle deflects by about $\theta = 40°$. Measure the current through the coil, determine B_{coil} and use this, θ, and your formula from 1 b) to determine B_{Earth}.

$I_{40} = .055$

$B_{coil} = 15\,\frac{4\pi \times 10^{-7}(.055)}{2(.06)} = 5.8 \times 10^{-7}$

$8.6 \times 10^{-6} \tan(40) = B_E$

$1.0 \times 10^{-5} = B_E$ ✓

e) Repeat part 1 d) for compass needle deflections of 50°, 60°, and 70°.

$I_{50} = .075$ A

$$\frac{(4\pi \times 10^{-7})15(.075)}{2(.06)}$$

$$B_{coil} = \frac{1.2 \times 10^{-5}\ T}{\tan 50}$$

$B_{Earth} = 9.9 \times 10^{-6}$ T ✓

$I_{60} = .129$ A

$$\frac{4\pi \times 10^{-7}(15)\ .129}{2(.06)}$$

$$B_{coil} = \frac{2.0 \times 10^{-5}\ T}{\tan 60}$$

$B_{earth} = 1.2 \times 10^{-5}$ T ✓

$I_{70} = .239$ A

$$\frac{4\pi \times 10^{-7}(15)\ .239}{2(.06)}$$

$$B_{coil} = \frac{3.75 \times 10^{-5}\ T}{\tan 70}$$

$B_{earth} = 1.4 \times 10^{-5}$ T ✓

f) Determine an average value for the earth's magnetic field based on your measurements (this is actually the horizontal component of the earth's magnetic field).

1.15×10^{-5} ✓

2 Forces between Two Parallel Currents

Since any current produces a magnetic field, and a magnetic field exerts a force on any other current, it must be possible for one current to exert a force on another current. Consider two parallel current carrying wires as illustrated in Fig. 2. The current in the lower wire points right. The current in the upper wire could point either left or right.

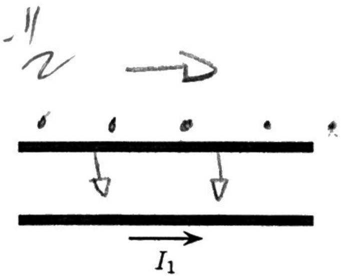


Figure 2: Parallel current carrying wires.

a) Determine the direction of the magnetic field produced by the lower wire at the location of the upper wire.

Out of the board. ✓

b) Suppose that the current in the upper wire points right. Use the magnetic field produced by the lower wire to determine the direction of the force that it exerts on

Force points down ✓

$F = I\vec{\ell}_1 \times \vec{B}$

the current in the upper wire.

Force points down ✓

c) Suppose that the current in the upper wire points left. Use the magnetic field produced by the lower wire to determine the direction of the force that it exerts on the current in the upper wire.

Force will point up ✓

d) Do parallel currents attract or repel? Do opposite currents attract or repel? Explain your answers.

parallel currents attract ✓
opposite currents repel

This rules can be investigated using a current balance, whose essential working parts are two rigid parallel wires through which the same current is passed. The current balance is designed so that the upper wire is free to pivot and the lower wire is fixed.

e) Set up the current balance with no additional mass in the pan. Let it come to rest and note the position of the reflected laser beam on the wall.

f) Trace the direction of the current through the lower wire and the upper wire. Use this to predict the direction of the force on the upper wire.

g) Turn the currents on and observe and record the motion of the wire. Does this agree with your prediction?

yes they were attracted

h) Repeat the previous parts for the case where the upper current direction is reversed.

yes they were repelled

N

.1m

N = 10

S

3 Exercises

a) A coil with radius 10 cm and 10 loops is placed along the earth's magnetic field. The horizontal component of the earth's magnetic field has magnitude 2.2×10^{-5} T. Determine the current required to deflect the compass needle by angles of 75°, 80° and 85°. Is it possible to get the needle to deflect through an angle of 90°?

$\vec{B}_{E_x} = 2.2 \times 10^{-5}$ T

$I_{75} = 1.5$ A

$I_{80} = 2.0$ A

$I_{85} = 4.0$ A

I_{90} = Not possible because it would mean that there was NO earth $\vec{B}$.

$B_{coil} = \tan\theta \, B_{earth}$

$I_{75} = \tan 75 \, B_{earth} \dfrac{2(.1m)}{10 \mu_0}$

$I_{80} = \tan 80 \, B_{earth} \dfrac{2(.1)}{10 \mu_0}$

$I_{85} = \tan 85 \, B_{earth} \dfrac{2(.1)}{10 \mu_0}$

$I_{90} = \tan 90 \, B_{earth} \dfrac{2(.1)}{10 \mu_0}$

b) In the coil experiment, the current is adjusted so that the compass needle deflects 45° to the east of north (i.e. points NE). The connections are reversed but the same current is maintained. Which way does the needle now point? Explain your answer.

the needle should point 315. the $\vec{B}_{coil}$ will be opposite direction as before.